TR-9

TECHNICAL REPORT

ELECTRIC WAVE STAFF
(HYDROGRAPHIC OFFICE MODEL MARK I)

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U. S. NAVY HYDROGRAPHIC OFFICE
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ABSTRACT

This report describes the development of and gives the operating instructions for using the Electric Wave Staff (Hydrographic Office Model Mark I). It combines the best features of a step-resistance gage developed by the Beach Erosion Board and the 50-Foot Spar Buoy Damping Disk System developed by the University of California Fluid Mechanics Laboratory. The gage has been developed for making direct recordings of wave action in ocean areas where the depth is greater than ½ wave length. The wave staff has been modified to improve its watertightness, eliminating the major weaknesses of the instrument in the past. Consideration is being given to adapting the instrument for use with a radio-buoy link.

F O R E W O R D

The Hydrographic Office, aware of the need for improved instrumentation in conducting hydrographic and oceanographic surveys, develops, tests, and evaluates new oceanographic instruments. The Electric Wave Staff (Hydrographic Office Model Mark I) is the first in a series of wave recorders developed and tested for deep-sea work. Comments are welcome on the operational value of this instrument.

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Captain, U. S. Navy
Hydrographer

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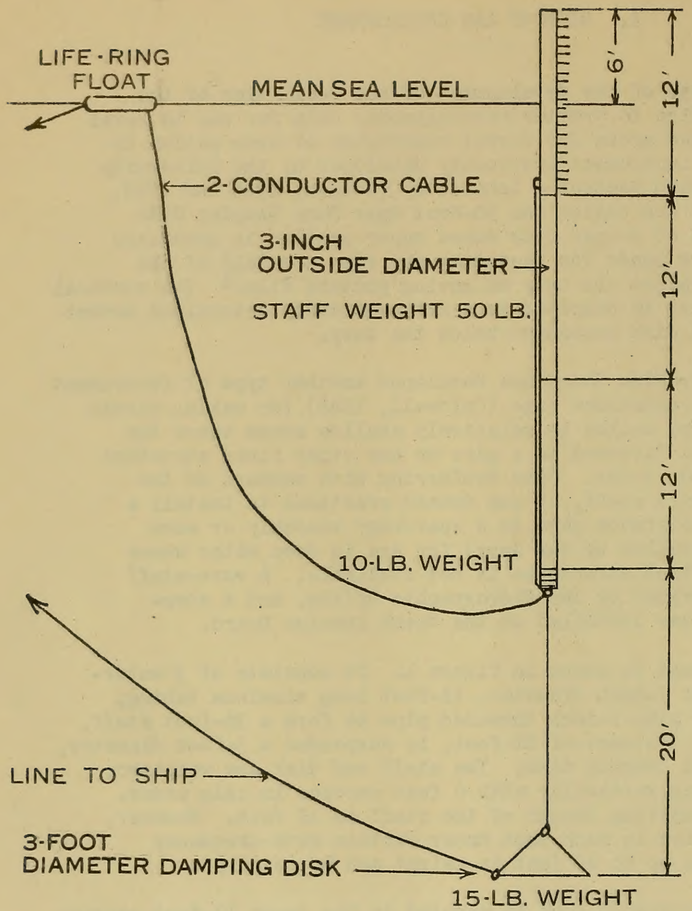
In the course of the development of the facilities of the Hydrographic Office to provide oceanographic data for use in naval operations, a need arose for direct recordings of wave action in deep water. An instrument previously developed by the University of California Fluid Mechanics Laboratory (Folsom, 1945 and 1947, and Warner, 1947) and called the 50-Foot Spar Buoy Damping Disk System, consists of a spar buoy whose upper portion is graduated in light and dark bands for recording the rise and fall of the water surface against the buoy on moving picture film.[1] The vertical motion of the buoy is dampened to a mathematically determined extent by a large metal disk suspended below the buoy.

The Beach Erosion Board has developed another type of instrument called the step-resistance gage (Caldwell, 1948) for making direct recordings of wave action in relatively shallow areas where the instrument can be fastened to a pier or any other fixed structure extending into the water. Upon conferring with members of the Beach Erosion Board staff, it was deemed practical to install a modified step-resistance gage in a spar-buoy assembly or wave staff (as it is called by the Navy) for use in deep water where the benefit of fixed structures is not available. A wave-staff assembly was provided by the Hydrographic Office, and a step-resistance gage was installed at the Beach Erosion Board.

The instrument is shown in figure 1. It consists of 3 water-tight sections of 3-inch diameter, 12-foot long aluminum tubing, coupled together with 1-inch threaded pipe to form a 36-foot staff. Below this, at a distance of 20 feet, is suspended a 3-foot diameter, corrugated, metal damping disk. The staff and disk are weighted, the staff floating vertically with 6 feet exposed in calm water. The effective measuring length of the staff is 12 feet. However, the vertical motion is such that under certain wave-frequency conditions, waves up to 20 feet in height can be measured.

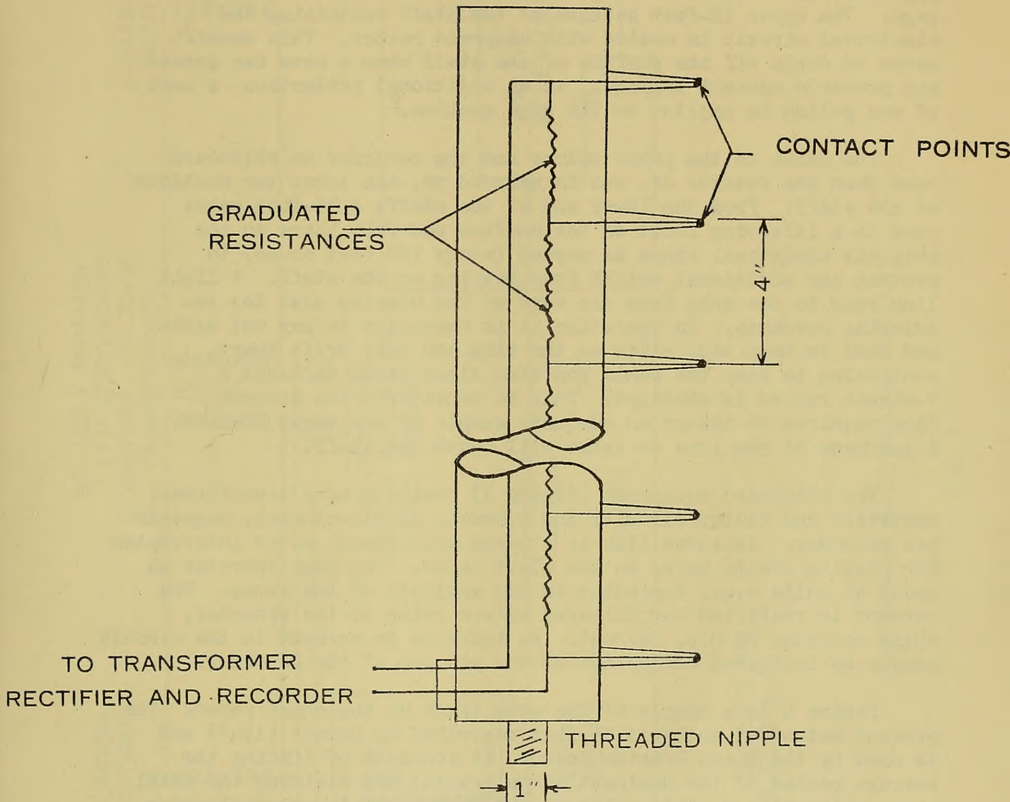
The step-resistance gage is mounted in the upper 12-foot section of the staff and consists of a series of 36 contact points spaced 4 inches apart, as shown in figure 2. Each contact point is an auto tire valve stem with the actual valve removed. A wire is run through the inside of the stem to its end, which is soldered over to form a contact surface with the water. The valve stems seem particularly suitable for the purpose because they are rugged, light, and easily

[1] The principal disadvantage of this method is the time and effort required to analyze the resulting film strip frame-by-frame for wave height and period.



ELECTRIC WAVE STAFF

FIG. 1



STEP–RESISTANCE GAGE SECTION

FIG. 2

cemented to a curved surface. Inside the staff and between each contact stem is placed an appropriate resistance in series. As a wave rises up the staff, submerging additional contact points, proportionately more current flows through the circuit as the parallel salt water current path reduces the resistance of the gage. The upper 12-foot section of the staff containing the electrical circuit is coated with neoprene rubber. This causes water to drain off the surface of the staff when a wave has passed and prevents current leakage. As an additional protection, a coat of wax polish is applied to the gage section.[2]

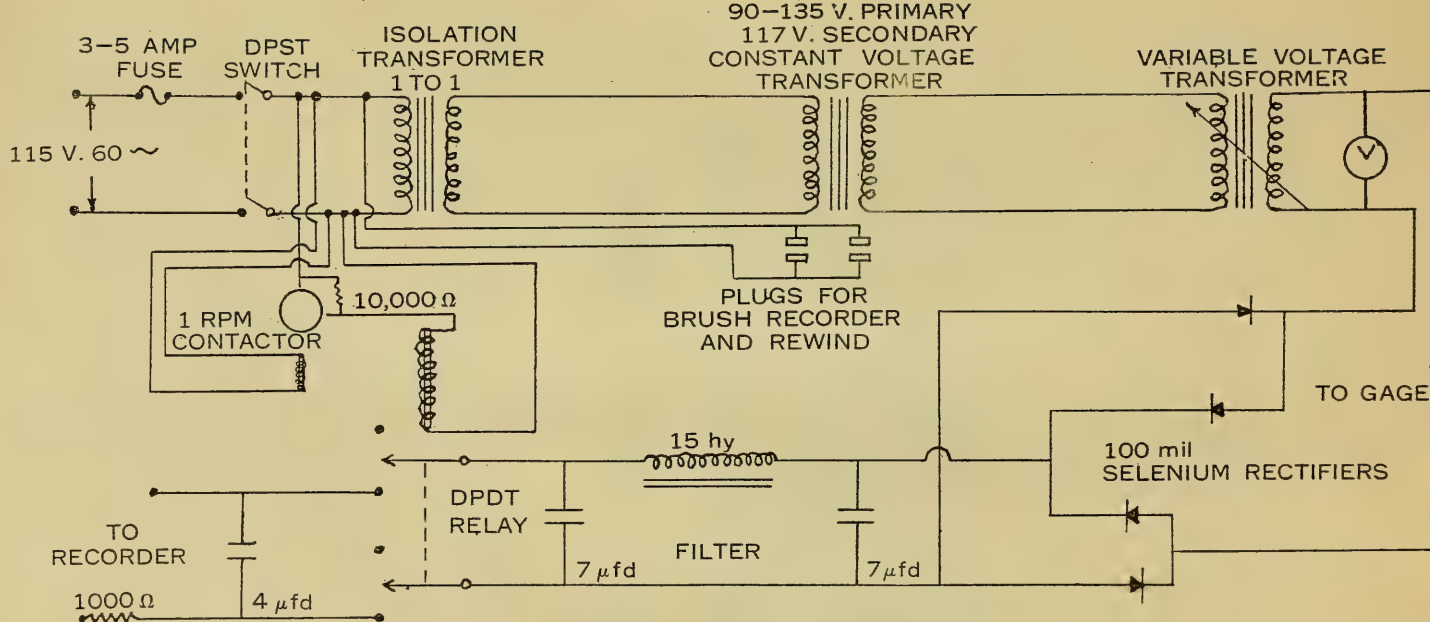
The cable to the power source and the recorder on shipboard runs down the outside of, and is secured to, the lower two sections of the staff. From the lower end of the staff, a 75-foot cable runs to a life-ring float on the surface and from there to the ship via additional rings as needed (every 100 feet or so) to prevent any additional weight from bearing on the staff. A light line runs to the ship from the edge of the damping disk for retrieving purposes. In operation it is necessary to pay out cable and line to keep them slack as the ship and buoy drift apart, continuing to keep the cable and line slack until at least a 7-minute record is obtained. This is considered the minimum time required to obtain an adequate sample of the waves present. A tautness of the line or cable will upset the staff.

The shipboard equipment (figure 3) consists of a transformer; rectifier and filter circuit; and a Brush, single-channel, magnetic pen recorder. Included also is a 1-rpm synchronous motor interrupter for placing minute marks on the chart paper. The gage operates on about 45 volts a.c., depending on the salinity of the water. The current is rectified and filtered before going to the recorder, which operates on d.c. current. An increase in current in the circuit causes an increased deflection of the pen arm of the recorder.

Figure 4 is a sample of the wave trace on the chart paper. The present method of analysis is that described by Warner (1947) and is used by the Beach Erosion Board. It consists of finding the average period of the dominant waves present and dividing the total observation time by this value to obtain the total number of waves of a given period which could occur in the observation time. This total number is divided by 3 and the highest $\frac{\text{total number}}{3}$ waves are averaged using a calibration scale. The scale shows the corresponding pen deflection for gage submergence and is for all practical purposes linear. This value is taken as the "apparent significant wave height."

Figure 5 shows the dynamic calibration curve for the 50-Foot Spar Buoy Damping Disk System, which is used for correcting the apparent height values obtained from the trace for the vertical

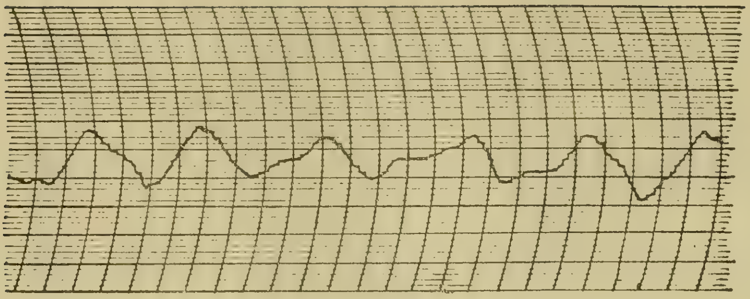
2 Recent modifications in the electrical section of the gage can be found in the Appendix.



RELAY CONTACTS NORMALLY CLOSED TO RECORDER TERMINALS. OPEN FOR 1/4 SECOND PER ONE MINUTE

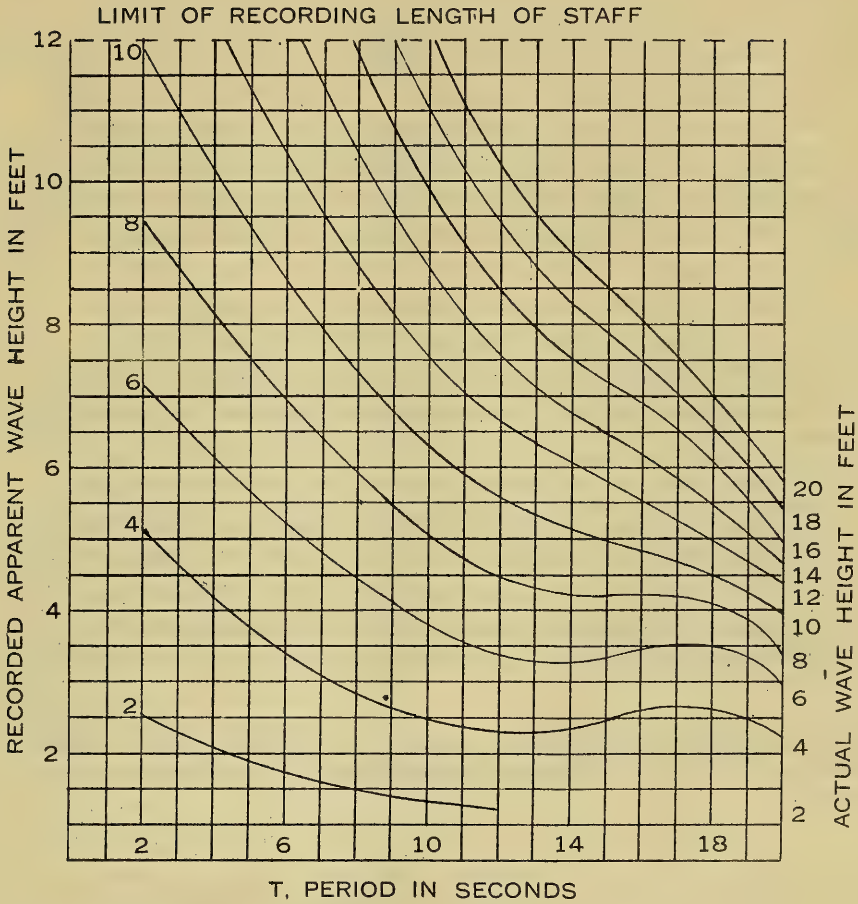
SHIPBOARD ELECTRICAL CIRCUIT

FIG. 3



24–SECOND PORTION OF WAVE TRACE OBTAINED WITH WAVE STAFF

FIG. 4



CALIBRATION CURVE – 50-FOOT DAMPING DISK SYSTEM

FIG. 5

motion of the staff assembly. This chart was drawn up by the University of California Fluid Mechanics Laboratory (Rauch, 1945) from a theoretical consideration of the water particle motion at the depth of the damping disk and from the relative motion of the disk through the water as the buoyant force on the staff changes due to wave action. The "true significant height" is obtained by entering the ordinate with the "apparent significant height" and the abscissa with the average frequency, interpolating between the curves plotted on the chart as necessary. Electrical-mechanical analyzers based on the auto-correlation function are being applied to ocean wave traces which show promise of more accurately describing the components of wave action (Pierson, 1951; Seiwell and Wadsworth, 1949; Seiwell, May 1950, Sept. 1950; and Snodgrass, 1950). Consideration is being given to the application of one of these methods to the electric wave staff records.

A field calibration check was made by the University of California in 115 feet of water using the photographic method with an anchored buoy and the floating 50-Foot Damping Disk System. The results from the floating system averaged 0.9 foot greater than from the anchored buoy system. The wave period at the time was about 10 seconds, which indicates waves of sufficient length were present to cause the bottom to compress the orbits of particle motion. As the calibration curves do not take into account any bottom effect, it would seem that the correction values introduced by the curves would be too large, thus attributing more motion to the staff than actually took place. This would account to some extent for the larger average value obtained with the floating system. It should be recognized here that using these calibration curves excludes the use of this instrument in areas having a depth less than 1/2 wave length where the bottom effect is present. Further field checks of this type are contemplated.

A small amount of data obtained on a recent oceanographic cruise has been compared with computed values using the Sverdrup-Munk method. The results were very encouraging, particularly with regard to wave height.

II. OPERATING INSTRUCTIONS

A. Assembling Staff and Preparing for Lowering

1. Lay out on deck the three sections of the wave staff, the damping disk, weights, suspension line, electrical cable, floats and retrieving line.

2. Check the contacts on the step-resistance gage to see that they are clean and bright. If necessary, burnish the contacts lightly with fine emery cloth to produce a bright surface. Rubdown the gage section with a clean dry cloth and apply DC4 grease sparingly as often as required to produce a water repellent surface, avoiding the contact points. Grease the end fittings of all three sections.

3. Assemble the three sections of the staff. Thread the 1-inch bolt on the bottom end of the staff.

4. Secure the damping disk to the bolt at the lower end of the wave staff by means of the suspension line and shackles provided so that the face of the damping disk is twenty feet from the lower end of the staff.

5. Shackle the fifteen-pound weight to the eye on the under side of the damping disk. Note: Sufficient weight should be used to float the assembly with about six feet of the step-resistance gage section exposed in calm water. On some staffs and in some areas this requires the use of the ten pound weight only.

6. Plug in the cable to the gage by means of the Joy plug and wrap with two layers of Scotch electric tape. Next tape the electrical cable along the rear of the three sections of the staff and the bolt eye at the bottom.

7. Make fast the end of the 1,000-foot cotton retrieving line to the eye on the edge of the damping disk.

8. Secure two 30- to 40-foot handling lines to the staff just above the two joints.

9. Attach the life ring or floats to the electrical cable either by manipulating the cable through the ring and the ring through the resulting cable loop, or by utilizing map hooks and tape. The first float should be 75 feet from the bottom of the staff and the rest approximately 100 feet apart.

10. Set the gage on deck with the contact points upright and clear of all metal objects.

B. Calibration and Test Procedure

Before the wave staff can be lowered over the side for operation, the gage and recorder must be calibrated and tested. This must be done before each lowering as follows:

1. Test the pen of the recorder for proper inking and pen pressure.

2. Connect the electrical cable from the wave staff to the input on the back of the recorder case. Plug in the power supply cable. Adjust the variac dial on the front of the recorder case to read about 52. Stand clear of the step-resistance gage section of the wave staff. Turn the main power supply switch to "On" position. This switch is located on the front of the recorder case. Next, adjust the manual lever on the side of the Brush recorder pen motor so that the pen trace is on the bottom line (nearest the front of the case) of the chart paper. When this is done, turn the main power switch to "Off" position.

3. After making certain that the main power switch is off, attach 25-foot wire leads to the uppermost and lowermost contact points and lower the two leads over the side into the water, assisted by sinkers. The lower ends of these leads should be bare. Care should be taken to secure these leads aboard ship to prevent accidental loss over the side.

4. When both leads are in the water, about 12 feet apart and away from the ship, stand clear of the gage and turn the main power supply switch to the "On" position. Adjust the variac knob in the center of the front panel so the recorder pen is on the top line (toward the back of the case) of the chart paper. With power off detach one of the leads. Then with power on, set the pen back on the bottom line by means of the manual adjusting lever on the side of the recorder pen motor. Attach the lead once more with the power off; and after turning the power on set the variac so that the pen is on the top line again. Repeat this operation until the pen is on the bottom line with lead detached and on the top line with lead attached.

5. Label the calibration run on the chart paper and record the voltage setting. Retain the calibration run with the record of each wave staff observation.

6. For most practical purposes, the gage calibration can be assumed to be linear.

C. Lowering and Operating the Electric Wave Staff

1. Make sure the main power supply switch is "Off". Lift the staff and damping disk over the side. Using the two handling lines and the retrieving line on the damping disk, lower the assembly into the water.

2. When the staff is waterborne, cast off the handling lines, keeping them clear of the contact points, and continue to lower the damping disk. Allow slack in the electrical cable and retrieving line.

3. Turn the main power supply switch to the "On" position and mark the point on the chart paper when the staff becomes upright in the water and settles to its normal depth. About six feet of the staff should be projecting above the surface in calm water.

4. Pay out the cable, with the floats or life rings attached, and the damping disk retrieving line. Allow slack at all times. If either becomes taut, the staff will list and will not record correctly. Pay out both line and cable, each of which is about 1,000 feet long, until at least 7 minutes (preferably 20 minutes) of record have been made from the time the staff became upright. If the cable should run out and become taut during the recording, shut off the recorder and mark the point on the chart, and then haul the staff an appropriate distance toward the ship by means of the damping disk retrieving line. Some of the cable should be retrieved at the same time to prevent excessive slack and possible fouling of the damping disk.

D. Retrieving the Electric Wave Staff

1. After the run is completed, turn off the main power and haul in the retrieving line and cable, keeping the strain on the line and not on the cable.

2. When the staff is alongside, retrieve the handling lines with a boat hook or grapnel. With the two handling lines and the damping disk retrieving line, hoist the staff and damping disk aboard.

3. Lay the staff on deck, keeping the contact points clear of the deck or any metal objects. Stand clear of the gage and turn the main power switch to "On" position. Check to see that the zero trace has returned to the lowest line of the chart paper (the one nearest the front of the case). If the zero trace is more than 5 lines above this, the gage section should be cleaned with fresh water, dried, and waxed, and the entire run should be repeated.

4. If the zero trace has returned properly to the lower line, then turn off the main power switch and disassemble the wave staff. Wipe dry the step-resistance gage section and clean and grease the coupling joints. It may be necessary to wash down the gage section with fresh water occasionally to prevent a coat of salt from forming, which would tend to hold a film of water on the gage. This film would produce erroneous recordings.

E. Recording Wave Staff Data

After the last wave trace, a line should be drawn across the chart paper to separate this run from subsequent ones. All printing should be done with the curved lines of the chart paper bowed out to the right and placed to the left of the last wave trace. The following information should be printed in ink on the recorder chart paper.

1. Ship, cruise, and wave observation serial number followed by the letter W.

2. Date: Give day, month, and year.

3. Time: Use G. M. T. Record the hour and minute at beginning of run and again at end of run.

4. Position: Give latitude and longitude of the observation.

5. Wind velocity in knots and direction in degrees true.

6. If known, give the current velocity in knots and direction in degrees true.

7. Give apparent direction of wave motion in degrees true.

8. Record variac setting.

9. Record wave staff serial number (located on cable outlet).

III. RECOMMENDATIONS

It is considered feasible to adapt the Electric Wave Staff for use with a radio buoy link to eliminate the dependence of the recording time on the length of cable usable in practical operation.

IV. ACKNOWLEDGEMENT

The writer expresses his gratitude to the Beach Erosion Board for their excellent cooperation during the construction of this instrument, to the University of California Fluid Mechanics Laboratory for their work in the development of the 50-Foot Damping Disk System, and to the Naval Ordnance Laboratory for providing facilities for a field test of the instrument.

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APPENDIX

MODIFICATION OF ELECTRIC WAVE STAFF (HYDROGRAPHIC OFFICE MODEL MARK I)

The Electric Wave Staff (Hydrographic Office Model Mark I) has been modified to improve its watertightness, eliminating the major weakness of the instrument in the past. The modification consists of imbedding the resistors of the step-resistance gage in Scotch Casting Resin within Micarta contact stems and connecting each set of the resistors by plastic-covered wire. Thus the electrical circuit of the step-resistance gage is completely water proofed except for the contact points. The aluminum tubing is flattened around the holes where the contact stems enter to provide a good seat. The contact stems are inserted and attached by means of Micarta hex nuts and washers. The tubing itself is coated with paint and Scotch electric tape to insulate the tubing from sea water in the vicinity of the contact stems. This is necessary to insure as long an external current path between contact points as possible, taking into consideration the water draining from the stems and tubing after the wave surface recedes. The contact surface is situated on the top of the stem near its extremity and all surfaces other than this are plated with DC4 silicone compound which breaks the surface water film rapidly. These provisions reduce the lag time following the recession of the wave surface to a fraction of a second. Working drawings are included in figure 6.

The Electric Wave Staff (H. O. Model Mark I) as modified has been tested aboard the Chesapeake Bay Institute Vessel MAURY and found to operate satisfactorily. Six instruments of the new design have been prepared.

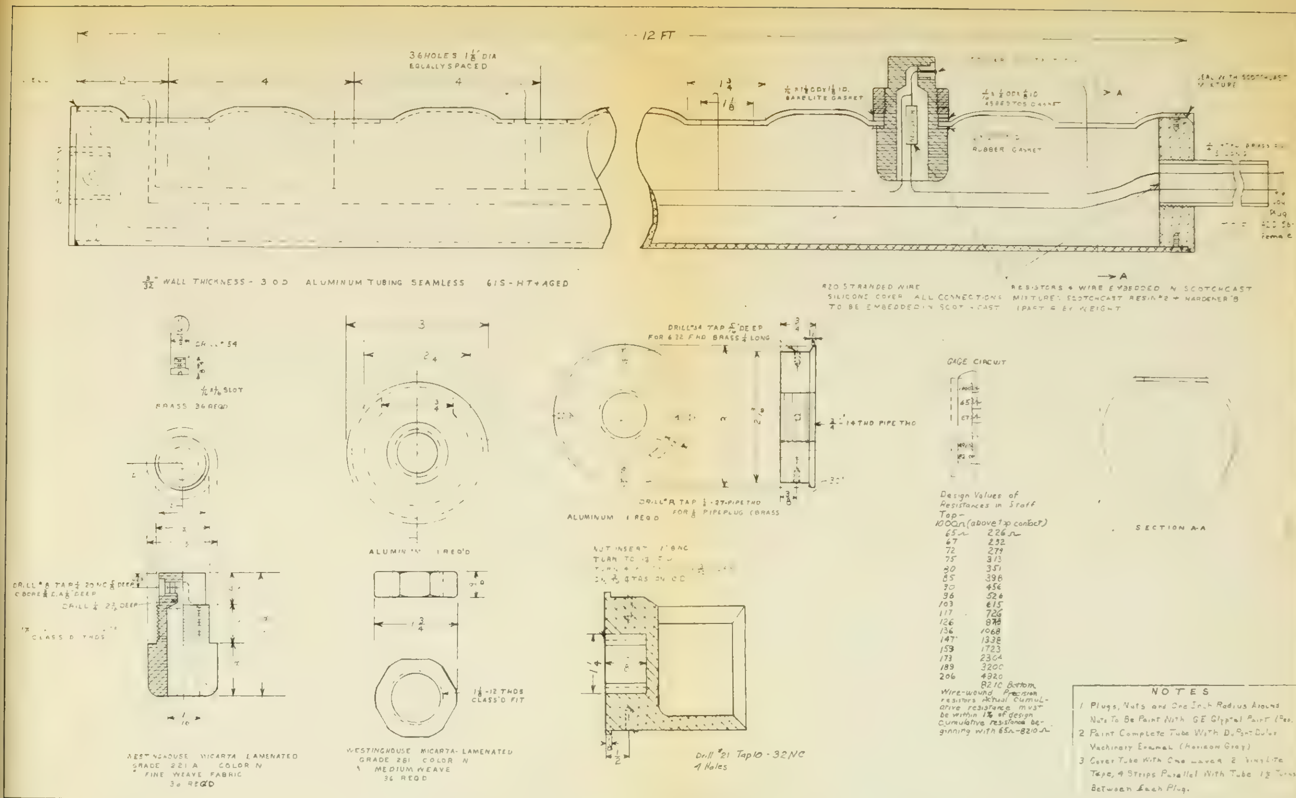

FIG. 6. MODIFIED STEP-RESISTANCE GAGE

U. S. Navy Hydrographic Office
ELECTRIC WAVE STAFF (HYDROGRAPHIC OFFICE MODEL MARK I), by Sidney H. Upham, March 1955. 13p. 5 figs. (H. O. TR-9).

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1. Oceanographic instructions
2. Oceanographic observations
3. Wave action recorder

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